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EVALUATION OF SCALES AND OTOLITHS FOR WALLEYES AND YELLOW PERCH AGE ESTIMATION

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Progress Report
No. 06-21

Evaluation of Scales and Otoliths for Walleye and Yellow Perch Age Estimation

by

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Special Report

Dingell-Johnson Project--F-21-R-36-38
Job Number--2102
Date---November 2006

Preface

Information presented in this report was collected during the period June 2003 through August 2005. Funding for this project was provided in part by Federal Aid in Sport Fish Restoration, (D-J) Project F-21-R-36-38, Job Number 2102. Copies of this report and reference to the data can be made with written permission of the authors or the Director of the Division of Wildlife, South Dakota Department of Game, Fish and Parks, Foss Building, Pierre, South Dakota, 57501.

We would like to thank Brian Blackwell, Gary Knecht, Quinton Phelps, Todd St. Sauver, Jamie Shepard and Matt Ward for their assistance with the collection and preparation of samples, participation in timed trials of preparing and aging structures and/or participation in the blind trials to compare fish aging using otoliths and scales. We would also like to thank Dr. Michael Brown for assistance with statistical analyses and Geno Adams, Dr. Brian Blackwell, Todd St. Sauver and Dr. David Willis for reviewing the manuscript .

Abstract

We compared the removal and processing times required when scales and otoliths were used to estimate ages of walleyes *Sander vitreus* and yellow perch *Perca flavescens* collected from three South Dakota lakes. On average, scales could be removed in less than half the time it took to remove otoliths from both walleyes (0.47 and 1.24 minutes) and yellow perch (0.39 and 0.84 minutes) . However, otoliths, which were viewed whole, required no additional processing time, while scale pressing required an additional 1.5 minutes per sample. When scale annuli were recorded on paper strips, scales and otoliths required a similar amount of time to read and total processing times were about a minute per sample less for otoliths. Without recording scale annuli, total processing times were similar for the two structures.

In blind aging trials with five readers of varying experience, mean yellow perch ages estimated from scales were consistently higher than those ages estimated from otoliths. When all five readers were included, walleye ages assigned using scales and otoliths were similar. However, if only the three most consistent readers for each structure were included, mean walleye ages estimated from otoliths were higher than those from scales. The difference was greatest for walleyes older than 4 years. Percent agreement among the five readers was higher for otoliths than for scales in yellow perch and walleyes, however, the difference in exact agreement between structures was not significant. Otoliths did not provide significantly more precise age estimates than scales for both species.

Growth and age structure parameters estimated from scale-aged and otolith-aged walleyes generally were similar for walleye populations in Lakes Herman, Madison, Sinai and Thompson, 2003-2005. However, the slopes of the regression lines (quadratic) of total length by age from scale- and otolith-aged walleyes differed for three of the four populations. Calculations made with otolith-aged walleyes provided more realistic estimates of asymptotic length for three of those populations. Information on yellow perch and walleye recruitment patterns in Lake Madison indicate that age structure keys developed using otoliths more accurately represented the true age structure of those populations. Based on the findings of this study and other research showing that otoliths consistently provide more precise and accurate age estimates than scales, we recommend using otoliths to age walleyes and yellow perch in waters surveyed by the Department of Game, Fish and Parks.

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Introduction

Estimating the age structure of sportfish populations has been an important component of summer adult fish population surveys in South Dakota for over two decades. Statistics on growth, mortality and population structure can be inferred from age structure data. Scales have traditionally been used for age estimation in South Dakota because preparation required less time, fish did not need to be sacrificed, lengths-at-age could be back-calculated and fisheries personnel were often more experienced with aging scales versus otoliths or spines.

Researchers in South Dakota began using otoliths to determine age of adult fish in the early 1990s. Kruse et al. (1993) found similar precision for ages assigned to black crappies *Pomoxis nigromaculatus* using scales and otoliths. Bister (2000) used otoliths to identify annuli in slow-growing Lake Alvin crappies *Pomoxis spp*. Lucchesi (2002) used otoliths to age slow-growing Lake Herman walleyes *Sander vitreus* after aging with scales produced an age structure that was highly inconsistent with age-0 recruitment data. With several of these studies, preparation involved fixing the otolith in epoxy and cutting thin transverse sections with an Isomet low speed saw. This was time consuming and considered unsuitable for aging the large number of samples collected during summer surveys.

Recently, whole-view and "cracked" otoliths have been used to age South Dakota yellow perch *Perca flavescens* (Blackwell and Hubers 2003, Isermann 2003), walleyes (Isermann et al. 2003; Lott et al. 2003) and bluegills *Lepomis macrochirus* (Edwards et al. 2005). "Cracked" otoliths are simply sectioned by hand and either polished with fine grit sandpaper, burned with an open flame, or viewed as is. Isermann et al. (2003) processed and read walleye otoliths (whole view) in just over half the time it took to process scales. Blackwell and Hubers (2003) reliably aged older yellow perch using "cracked" otoliths. Edwards et al. (2005) aged 2-5 year old bluegills reliably with whole-view otoliths, but recommended "cracked" otoliths for aging fish 6 years and older.

Several studies have indicated that saggital otoliths provide a more accurate (Erickson 1983; Heidinger and Clodfelter 1987; Ross et al. 2005) and precise (Campbell and Babaluk 1979; Belanger and Hogler 1982; Marwitz and Hubert 1995; Niewinski and Ferreri 1999;

Kocovsky and Carline 2000; Hoxmeier et al. 2001; Isermann et al. 2003) approach to age estimation than scales, especially with older fish. However, regional fisheries staff were still reluctant to use otoliths due to perceived problems that included the additional time and expertise required to extract and read these structures.

The first objective of this study was to compare extraction and processing times for scales and otoliths of walleyes and yellow perch. Second, we wanted to compare mean ages and relative precision of ages assigned using scales and otoliths. Our third objective was to compare age structure and growth estimates for yellow perch and walleye populations using fish aged with scales and otoliths.

Methods

Comparison of extracting, processing, and reading times for scales and otoliths

Experimental-mesh, monofilament gill nets were used to collect walleye and yellow perch from Lakes Herman, Madison, and Sinai during summer 2003. Gill-net dimensions were 46 x 1.6 m with six 7.6-m panels having mesh sizes of 13, 19, 25, 32, 38 and 51 mm (bar measure). Nets were set overnight and effort ranged from three to six net nights per lake.

Fish were measured and aging structures were extracted on site using standard lake survey protocol (St. Sauver et al. 2005). Time to measure (total length, TL), weigh (g) and take scales from the walleyes and yellow perch in each net were recorded. Scales were collected from just below the lateral line immediately posterior to the dorsal fin and placed in envelopes. Time to measure, weigh and extract saggital otoliths from the same group of fish was then recorded. Otoliths were wiped clean and placed into clear plastic vials. Different individuals were used to remove structures at each of the three lakes to account for variability in removal times among personnel with varying experience.

Time to process scale samples and examine scales and otoliths was recorded by species for all samples from each of the three lakes. In the lab, four to six scales from each fish were pressed (standard roller press) onto acetate slides for viewing. Scale images were viewed with a microfiche projector (32X magnification). The focus, annuli and margin of each scale were recorded on paper strips and digitized using WinFin Data Entry Program 4.4 (Francis 2003a). Otoliths were submersed in water in a black dish and viewed whole under a dissecting microscope (15-40X magnification). Mean times to extract, process and read scales and otoliths were calculated for walleyes and yellow perch and compared using a *t*-test.

Comparison of mean ages and relative precision of ages assigned using scales and otoliths

Paired samples of 20 walleye and 20 yellow perch scales and otoliths were selected from the 2003 Lakes Herman, Madison, Sinai and Thompson samples. Fish of varying size (and estimated age) were selected for the blind trials and the paired scale and otolith samples were then assigned a separate, random order. Each structure was read by five individuals with varying experience. A mean age was calculated for each structure from ages assigned by the five readers. Mean ages were also calculated from ages assigned by the three individuals with the highest rate of agreement. Mean ages assigned using scales and otoliths were compared using a *t*-test.

The coefficient of variation (CV = 100 X SD/mean) was used as a measure of the relative precision between readers (Chang 1982; Isermann et al. 2003). Coefficient of variation was calculated for all five readers and for the three readers with the highest rate of agreement. Percent agreement for ages assigned to otoliths and scales was also calculated for the five readers and for the three and four readers with the highest rate of agreement. Percent agreement for the two structures was compared using chi-square analysis.

Comparison of age structure and growth parameters from fish aged with scales and otoliths

Scales and otoliths were taken from walleyes and yellow perch captured in gill nets set during summer surveys on Lakes Herman, Madison, Sinai and Thompson from 2003 to 2005. Scales and otoliths were aged by co-authors, Johnson and Lucchesi, respectively. Ages were typically estimated for otoliths of younger fish ($\leq$ age-4) in whole view. Preparation of otoliths from older fish involved “cracking” or breaking the otolith through the nucleus and burning the fractured area under a propane torch. Next, the half-otolith was mounted in putty, cleared with vegetable oil, illuminated with a single fiber-optic strand and viewed under a dissecting scope at 30-40X magnification.

Walleye growth, described using mean length at age and von Bertalanffy growth coefficients (k, t_0, and L_{∞}), was estimated using ages assigned with scales and otoliths. Age-length data were pooled for 2003-2005. WinFin Analysis Program 2.3 (Francis 2003b) was used to calculate mean lengths at age (at the time of capture) and catch per unit effort (CPUE) by age. Von Bertalanffy growth coefficients were estimated using Fisheries Analysis and Simulation Tools (FAST 2.0, Slipke and Maceina 2002) and predicted lengths at age were plotted to visually assess differences in growth estimated from the two structures. Additionally, differences in walleye growth rates were tested by comparing the regression line slopes of total length (quadratic) by age using analysis of covariance.

Results

Whole viewed otoliths required less time to process than scales for walleye and yellow perch (Table 1). However, if time to record annuli on paper strips was excluded, processing times for otoliths and scales were nearly identical. It took over twice as long to extract a pair of otoliths than to remove scales (Table 1), but scales required an additional 1.5 minutes per sample to press onto acetate slides. Viewing times were similar for both structures when scale annuli were recorded onto paper strips. Viewing time decreased by over a minute per sample when annuli were not recorded. Time to crack, burn, and mount otoliths in clay, the methodology used to age older fish in 2004 and 2005, was not measured, but would have added significantly to the total processing time.

The regression slope between walleye mean otolith age and mean scale age was not significantly different from one (Figure 1; $t = -0.20$, $P = 0.93$) when ages assigned by all five readers were included. The relationship was marginally significant ($t = -2.13$, $P = 0.05$) when mean age was calculated from ages assigned by the three readers with the highest rate of agreement. They assigned older ages to larger walleyes with otoliths than with scales. (Figure 1).

The regression slope between yellow perch mean otolith age and mean scale age was significantly different from one for five readers (Figure 1, $t = 8.03$, $P < 0.001$) and three readers ($t = 4.95$, $P < 0.001$). Older ages were assigned with scales to 2- to 5-year-old yellow perch than with otoliths (Figure 1). Agreement between readers was typically higher for

Table 1. Mean removal, processing, viewing and total processing times (min/sample) for scales and otoliths of walleye and yellow perch collected from three eastern South Dakota lakes during summer 2003. Standard errors are reported in parentheses.

Walleye				
Structure	Removal time	Processing time	Viewing time	Total processing time
Scales	0.47 (0.04)	1.40 (0.07)	2.49 (0.48)	4.36 (0.37)
Otoliths	1.24 (0.10)		2.28 (0.46)	3.52 (0.45)

Yellow Perch				
Structure	Removal time	Processing time	Viewing time	Total processing time
Scales	0.39 (0.08)	1.47 (0.09)	1.57 (0.19)	3.44 (0.22)
Otoliths	0.84 (0.07)		1.60 (0.11)	2.44 (0.05)

otoliths than scales (Table 2). The difference in exact agreement was significant for yellow perch, but not for walleye. Exact agreement with both structures was relatively low for walleyes ranging from 0% (scales with five readers) to 45% (otoliths with three readers). Ages assigned to walleye by at least one of the five readers often differed by 2 years or more, especially with scales (Table 2). Agreement rates were consistently higher for yellow perch than walleyes (Table 2), and the difference in assigned ages was seldom more than 1 year. Variation in agreement rates among pairs of readers was substantially less for yellow perch than for walleyes (Figure 2).

The mean CV was consistently greater for ages assigned with scales, however, the difference was never significant (Table 3, $t_{abs} < 1.2$, $P > 0.24$). The mean CV with walleye ages was consistently higher than with yellow perch ages (Table 3). This difference in mean CV was significantly less for yellow perch aged with otoliths by three readers ($t = -2.06$, $P = 0.05$).

There was relatively high agreement between ages assigned using scales and otoliths to the 2003-2005 walleye and yellow perch samples (Appendix 1). Assigned ages often

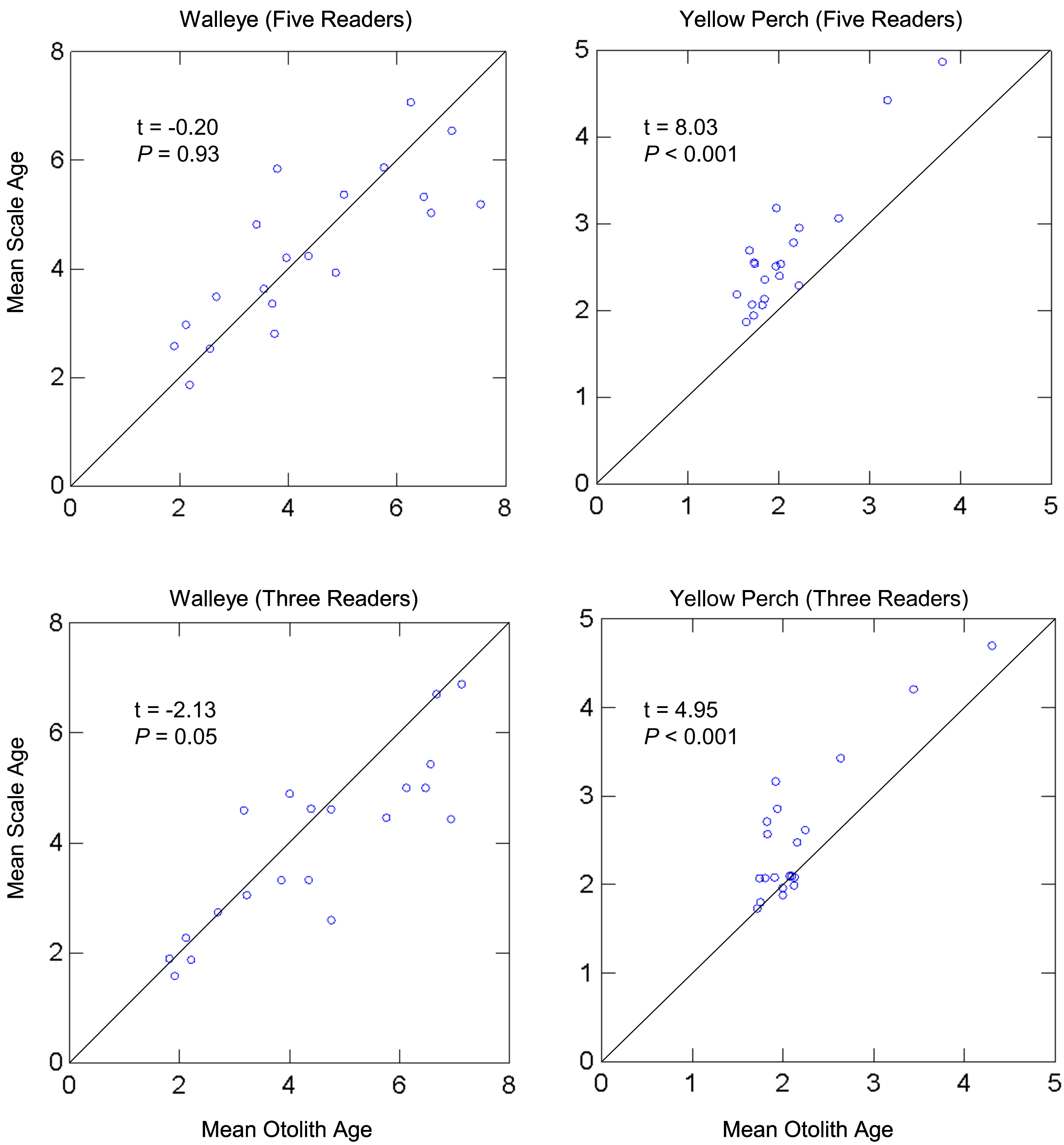

Figure 1. Age bias plots for walleye and yellow perch sampled from four eastern South Dakota waters, 2003, comparing average ages estimated from scales and otoliths read by five and three individuals. Solid black line represents a 1:1 relationship. Probability values (P) are associated with *t* tests to compare mean ages.

Table 2. Percentage agreement of walleye and yellow perch age estimates between the five readers (and the three and four readers with the highest rate of agreement) participating in blind trials to age 20 walleyes and 20 yellow perch collected from four eastern South Dakota lakes during summer 2003 . Values of percent agreement denoted by different letters were significantly different at $P \leq 0.05$.

Walleye

Structure	Percent exact agreement Three readers	Four readers	Five readers
Scales	30 z	10 z	0 z
Otoliths	45 z	20 z	10 z

Walleye

Structure	Percent agreement (± 1 year) Three readers	Four readers	Five readers
Scales	55 z	30 z	20 z
Otoliths	80 y	70 y	35 y

Yellow perch

Structure	Percent exact agreement Three readers	Four readers	Five readers
Scales	45 z	20 z	15 z
Otoliths	85 y	75 y	30 y

Yellow perch

Structure	Percent agreement (± 1 year) Three readers	Four readers	Five readers
Scales	100 z	100 z	65 z
Otoliths	100 z	100 z	95 y

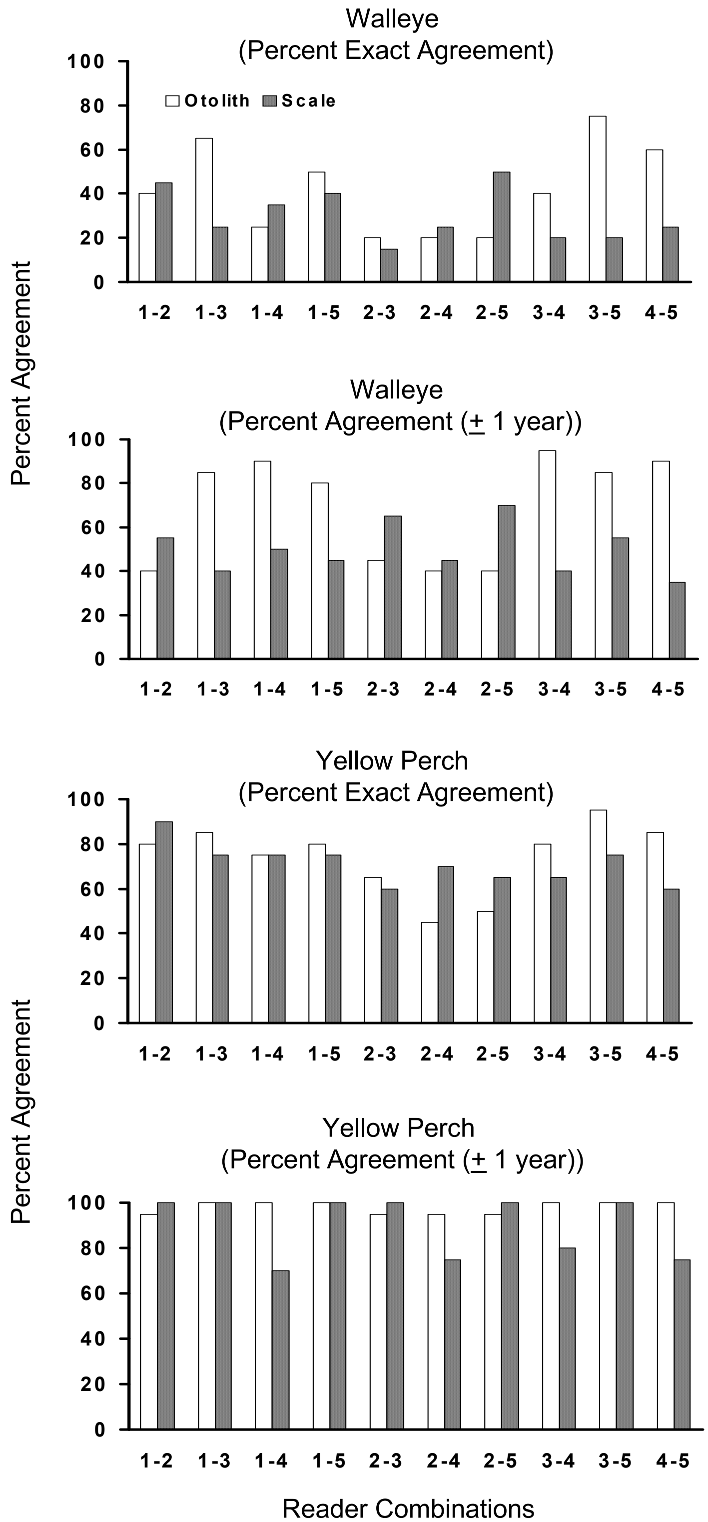

Figure 2. Percentage agreement in ages assigned by various pairs of readers using scales (white bars) and otoliths (dark bars) in blind trials to age 20 walleyes and 20 yellow perch collected from four eastern South Dakota lakes during summer 2003 .

Table 3. Mean coefficient of variation (CV = 100 X SD/mean) between reader age assignments for five readers (and three readers with the highest rate of agreement) participating in blind trials to age 20 walleyes and 20 yellow perch collected from four eastern South Dakota lakes during summer 2003 .

	Walleye		Yellow perch	
Structure	Five readers	Three readers	Five readers	Three readers
Scales	24.5 z	15.1 z	20.8 z	9.9 z
Otoliths	21.3 z	13.4 z	16.2 z	6.1 z

differed by less than 1 year and there were no persistent patterns such as walleyes or yellow perch aged with otoliths always being older than those aged with scales (Appendix 1). Although larger differences in walleye ages commonly occurred with older fish, a surprisingly high number of younger walleyes (2-4 years old), especially from Lake Thompson, were assigned different ages with otoliths and scales.

Mean catch per unit effort (CPUE) and mean length by age estimated from walleyes aged using scales and otoliths did not differ substantially (Appendix 2). The asymptotic length (L_∞) ranged from 534 to 1,574 mm and 616 to 927 mm for walleyes aged with scales and otoliths, respectively (Table 4). Von Bertalanffy predicted lengths at age were similar for scale- and otolith-aged walleyes from Lakes Herman and Thompson (Figure 3). Greater predicted lengths for older walleyes were estimated from scale-aged than otolith-aged fish from Lake Sinai. On Lake Madison, growth curves estimated from the two structures differed substantially (Figure 3). The slopes of the regression lines of total length (quadratic) by age differed significantly ($F > 3.74$, $P < 0.05$) for scale-aged and otolith-aged walleyes for three of the four populations. The slopes were similar for Lake Herman ($F = 1.63$, $P = 0.20$).

Discussion

Additional time required to extract and process saggital otoliths over scales has been the greatest deterrent to their use as a primary aging structure in Region III. Previous techniques involved fixing them in epoxy and cutting thin slices with an Isomet low speed saw. This process was very time consuming and could not be efficiently applied to the large number of aging samples (> 1,000) collected annually in Region III. Additionally, the

Table 4. Von Bertalanffy growth coefficients for walleyes aged with scales and otoliths collected from populations in four eastern South Dakota lakes, 2003-2005.

Walleye Population	Growth constant (k)	Length at time zero (t_0, mm)	Asymtotic length (L_∞, mm)
Herman			
Scales	0.459	-0.068	534
Otoliths	0.336	-0.228	616
Madison			
Scales	0.178	-0.335	758
Otoliths	0.407	0.753	623
Sinai			
Scales	0.123	-1.369	967
Otoliths	0.159	-1.181	752
Thompson			
Scales	0.036	-3.308	1,574
Otoliths	0.081	-2.273	927

regional staff was more experienced aging scales and lengths at age could be back-calculated from the scale annuli.

Isermann et al. (2003) demonstrated that whole-view otoliths were a more time-efficient method for aging walleyes than scales or dorsal spines. Boxrucker (1986) and Kruse et al. (1993) also suggested that aging whole-view otoliths was less time-consuming. Total processing times were somewhat less for whole-view otoliths than scales in this study. Total processing times would have been nearly identical had scale annuli not been recorded on paper strips. In this study as with Isermann et al. (2003), removal times were two to three times greater for otoliths suggesting an increase in the amount of time spent in the field. However, time will be saved in the laboratory as otoliths viewed whole required no further processing prior to viewing while scales are often pressed onto acetate slides. Viewing times were similar when scale annuli were not recorded.

Time to section or "crack" and burn otoliths was not included in the comparison of total processing times. Typically, only a small number of otoliths would require cracking as most of the sample is comprised of younger fish, especially with yellow perch. Only about

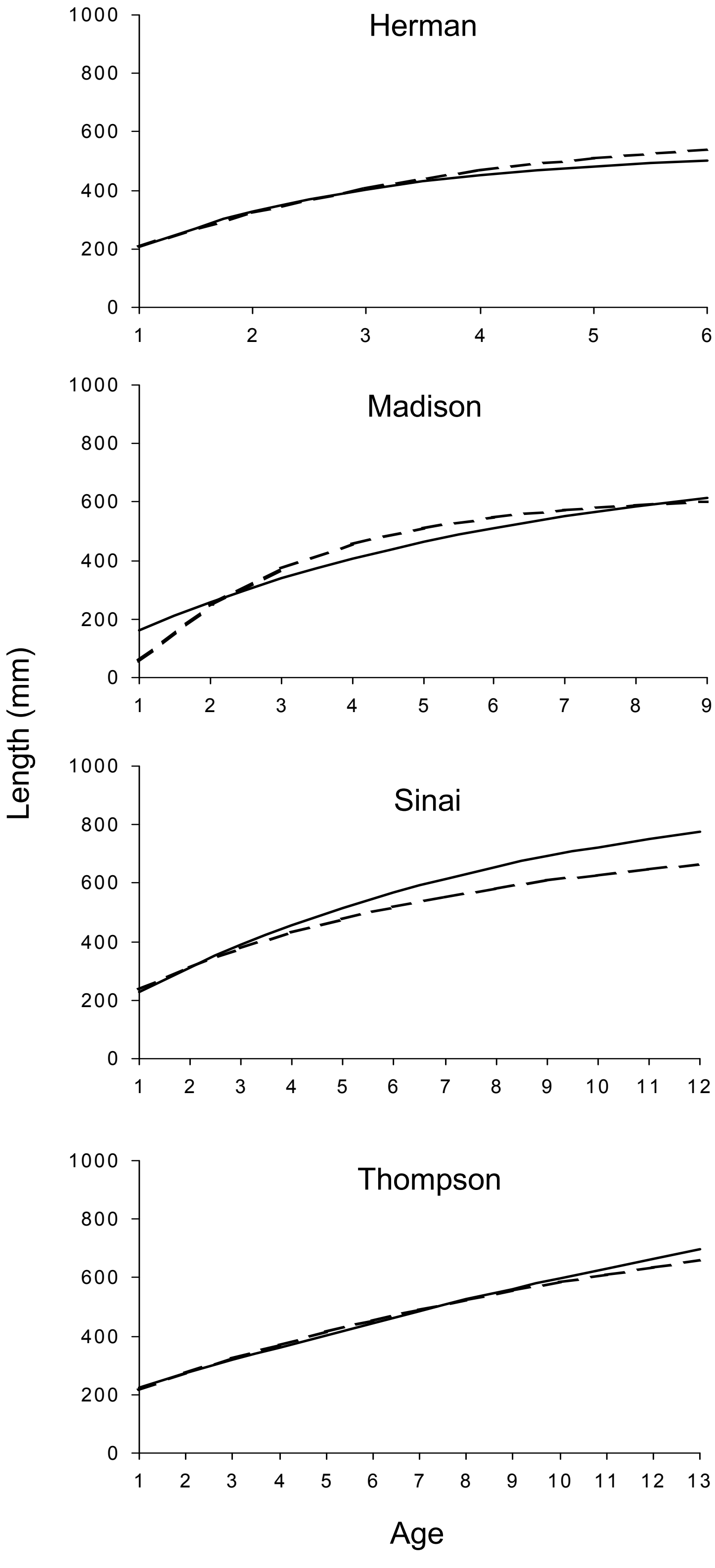

Figure 3. Von Bertalanffy growth curves for walleye aged with scales (solid line) and otoliths (dashed line) that were collected from four eastern South Dakota lakes, 2003-2005.

13% of walleyes and less than 1% of yellow perch from the 2003-2005 Lakes Herman, Madison, Sinai and Thompson gill-net samples were assigned ages of 5 years or older. Isermann et al. (2003) cited studies by Erickson (1983), Mero (1992) and Marwitz and Hubert (1995) to illustrate that exploited walleye populations are commonly dominated by younger fish (ages 1-5), and therefore, whole-view otoliths could reliably be used to estimate ages for most of the sample.

Otoliths provided better agreement among readers than scales, although the difference was not significant for walleyes. Several other studies have shown higher agreement rates with otoliths in aging walleyes (Kocovsky and Carline 2000; Isermann et al. 2003) and yellow perch (Niewinski and Ferreri 1999). Percent exact agreement between pairs of readers for both species in this study was generally lower than in other studies (Erickson 1983; Niewinski and Ferreri 1999; Kocovsky and Carline 2000; Isermann et al. 2003) and may reflect the wide variation in experience between the five readers. The higher agreement rates in ages assigned to yellow perch over walleyes were most likely due to the younger age of yellow perch than walleyes used in the blind aging trials.

Otoliths and scales provided similar precision for aging walleyes and yellow perch in this study. Although the difference was not significant, the coefficient of variation between reader age assignments was always lower for otoliths than scales. Studies have consistently shown higher precision in ages assigned with otoliths than with scales in walleyes (Kocovsky and Carline 2000, Isermann et al. 2003), yellow perch (Robillard and Marsden 1996; Niewinski and Ferreri 1999), crappies (Boxrucker 1986; Hammers and Miranda 1991; Ross et al. 2005) and bluegills (Hoxmeier et al. 2001). Similar precision in ages assigned with the two structures was observed for black crappies *Pomoxis nigromaculatus* (Kruse et al. 1993) and black bass *Micropterus spp*. (Long and Fisher 2001). Latitudinal gradient has been cited as one factor affecting the precision of ages determined from scales in centrarchids (Kruse et al. 1993; Hoxmeier et al. 2001). Scales provide more precise age estimates in northern latitudes than southern latitudes because distinct winters permit the formation of distinguishable annuli on scales as well as otoliths. Hoxmeier et al. (2001) noted that latitude within the state of Illinois affected precision with scale-aging, but not otolith-aging in bluegills. Difference in latitude of lakes in this study was minimal (< 30 km) and should have had little effect on aging precision.

Agreement between ages assigned to otoliths and scales by the authors for the 2003-2005 walleye and yellow perch samples was higher than agreement in the blind aging trials. The authors had substantially more experience than several of the trial participants in aging both structures, suggesting that reader experience may have affected bias and precision. Another factor, which positively influenced agreement in aging by the authors, was knowledge of fish length and population statistics for the samples being aged.

Growth and age structure parameters estimated from ages assigned with scales and otoliths did not differ substantially. Calculations made with otolith-aged walleyes provided more realistic estimates of asymptotic length on Lakes Thompson, Sinai and Herman. The only large difference in lengths-at-age between scale- and otolith-aged fish occurred with older Lake Sinai walleyes. These results suggest that management actions based on estimates of growth, age structure or mortality would not be significantly influenced by the type of structure used.

Although there were no known-age fish in this study, knowledge of recruitment patterns provided some evidence of greater accuracy in ages assigned with otoliths. Aging with otoliths of Lake Madison yellow perch in 2002 indicated an exceptionally large 2001 year class, while aging with scales suggested that two similarly large year classes were produced in 2000 and 2001 (Figure 4). Subsequent aging in 2003 and 2004 confirmed that a single 2001 year class was solely responsible for the high yellow perch CPUE. In 2001, there was exceptional yellow perch production in several large natural lakes across eastern South Dakota.

Aging of Lake Madison walleyes provided another indication that ages assigned with otoliths were more accurate than with scales. Fall electrofishing showed production of a weak walleye year class in 2002 (unstocked year) and a strong year class in 2003 (fingerling-stocked year). Walleyes, collected during the 2005 adult population survey, were aged with otoliths as 2-year olds from the 2003 year class (42 of 44 sampled), while aging with scales

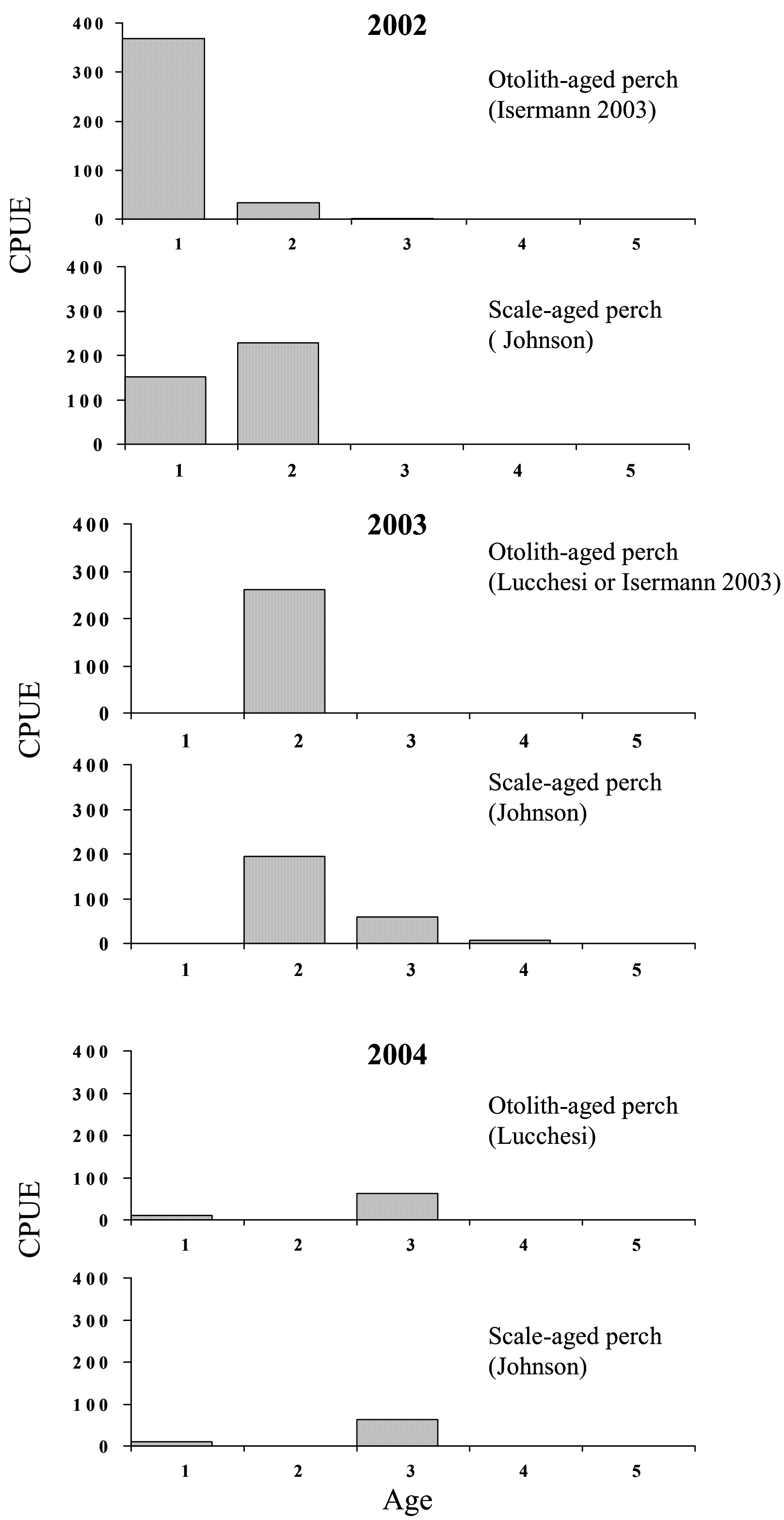

Figure 4. Mean catch per unit effort by age group for yellow perch collected in summer gill nets from Lake Madison, 2002-2004.

suggested a much greater contribution from the weak 2002 year class (Appendices 1 and 2). Prior aging of 2004 survey samples confirmed the lack of contribution by the 2002 year class.

Studies to evaluate reader accuracy with freshwater sport fish are rare due to the relative scarcity of reference collections of known-age fish. Buckmeier (2002) found highly variable accuracy in readers aging young (ages 0-3; 72-100%) and old (ages 4-14; 36-100%) known-age largemouth bass *Micropterus salmoides* using otoliths. Based on his results, he recommended that agencies establish acceptable levels of accuracy and bias, periodically test readers, and not allow readers failing to meet the criteria to independently estimate fish age without further training. To overcome problems with the limited supply of known-age fish, Campana (2001) suggested sharing reference collections among agencies, potentially through current technologies such as digital imaging and the Internet. In South Dakota, hatchery-reared walleyes marked with oxytetracycline are beginning to provide a source of known-age fish. These fish should provide some preliminary evaluation of accuracy in assigned ages.

Management Recommendations

We would recommend using otoliths to age walleye and yellow perch in waters being surveyed annually by the Department of Game, Fish, and Parks. Annual collection of aging structures allows us to follow yearly growth of cohorts and reduces the need for back-calculated lengths-at-age. Total processing times were similar for both structures and sacrificing fish to collect otoliths is not an issue with gill nets being used to sample both species. Although not significant, otoliths consistently had a lower coefficient of variation with age estimates and there was some evidence that otoliths may have provided greater accuracy in estimating yellow perch and walleye ages. Finally, a majority of the research comparing the two structures has concluded that otoliths provide better precision or accuracy in estimating ages than scales.

This study also highlights the importance of reader experience in obtaining reliable age estimates. Exact agreement between five readers aging walleyes was 10% or less for both structures in this study. Differences in percent agreement between pairs of experienced readers were substantially lower than when paired with an inexperienced reader. Thus, it is imperative that scales or otoliths be aged by experienced readers or at least under the direct supervision or review of an experienced reader to obtain reliable age estimates.

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Appendix 1. Comparison of yellow perch and walleye ages assigned using scales and otoliths for populations in four eastern South Dakota lakes, 2003-2005.

2003 Lake Herman Yellow Perch

Age Assigned Using Scales

Age Assigned Using Otoliths

	1	2	3	4	5	6	7	8	9	10	11	12
		41	8	2								
3		1	1	2								
4						1						
5						1						
6												
7												
8												
9												
10												
11												
12												

2003 Lake Herman Walleyes

Age Assigned Using Scales

Age Assigned Using Otoliths

	1	2	3	4	5	6	7	8	9	10	11	12
1												
2		28	2									
3			20	2								
4				1								
5					4							
6						1						
7												
8						1						
9												
10												
11												
12												

Appendix 1. Continued

2005 Lake Herman Yellow Perch
Age Assigned Using Scales

Age Assigned Using Otoliths

	1	2	3	4	5	6	7	8	9	10	11	12
1	5											
2												
3												
4				25	2							
5												
6												
7												
8												
9												
10												
11												
12												

2005 Lake Herman Walleyes
Age Assigned Using Scales

Age Assigned Using Otoliths

	1	2	3	4	5	6	7	8	9	10	11	12
1	2											
2		24										
3												
4					1							
5												
6												
7												
8												
9												
10												
11												
12												

Appendix 1. Continued

2003 Lake Madison Yellow Perch
Age Assigned Using Scales

Age Assigned Using Otoliths

	1	2	3	4	5	6	7	8	9	10	11	12
1												
2		28	9	1								
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												

2003 Lake Madison Walleyes
Age Assigned Using Scales

Age Assigned Using Otoliths

	1	2	3	4	5	6	7	8	9	10	11	12
1	3											
2		6										
3					1							
4				6	6		1					
5												
6					2							
7							1	1				
8												
9												
10												
11												
12												

Appendix 1. Continued

2004 Lake Madison Yellow Perch

Age Assigned Using Scales

Age Assigned Using Otoliths	1	2	3	4	5	6	7	8	9	10	11	12
1	14											
2												
3			33									
4												
5												
6												
7												
8												
9												
10												
11												
12												

2004 Lake Madison Walleyes

Age Assigned Using Scales

Age Assigned Using Otoliths	1	2	3	4	5	6	7	8	9	10	11	12
1	20											
2			3									
3			1									
4												
5				1	1							
6					1							
7					1							
8												
9												
10												
11												
12												

Appendix 1. Continued

2005 Lake Madison Yellow Perch

Age Assigned Using Scales (columns); Age Assigned Using Otoliths (rows)

	1	2	3	4	5	6	7	8	9	10	11	12
1	9											
2		12										
3			1									
4				27	1							
5												
6												
7												
8												
9												
10												
11												
12												

2005 Lake Madison Walleyes

Age Assigned Using Scales (columns); Age Assigned Using Otoliths (rows)

	1	2	3	4	5	6	7	8	9	10	11	12
1	1											
2		33	9									
3												
4												
5								1				
6												
7												
8												
9												
10												
11												
12												

Appendix 1. Continued

2003 Lake Sinai Yellow Perch
Age Assigned Using Scales

Age Assigned Using Otoliths

	1	2	3	4	5	6	7	8	9	10	11	12
1												
2		34	2									
3		2	5	1								
4		1	1	1	1	1						
5												
6												
7												
8												
9												
10												
11												
12												

2003 Lake Sinai Walleyes
Age Assigned Using Scales

Age Assigned Using Otoliths

	1	2	3	4	5	6	7	8	9	10	11	12
1	1											
2		16										
3			3									
4				1	2							
5		1	2		23	1	1					
6						1						
7					1							
8						1						
9												
10												
11												
12												

Appendix 1. Continued

2004 Lake Sinai Yellow Perch

Age Assigned Using Scales

Age Assigned Using Otoliths

	1	2	3	4	5	6	7	8	9	10	11	12
1	12											
2		10	1									
3			23	1								
4												
5												
6												
7												
8												
9												
10												
11												
12												

2004 Lake Sinai Walleyes

Age Assigned Using Scales

Age Assigned Using Otoliths

	1	2	3	4	5	6	7	8	9	10	11	12
1	4											
2		5	1									
3			6	2								
4				1								
5												
6					1	1						
7												
8												
9												
10									1			
11												
12							1					

Appendix 1. Continued

2005 Lake Sinai Yellow Perch

Age Assigned Using Scales

Age Assigned Using Otoliths

	1	2	3	4	5	6	7	8	9	10	11	12
1	12	1										
2		20	1									
3			3	2								
4				21	1	1						
5												
6												
7												
8												
9												
10												
11												
12												

2005 Lake Sinai Walleyes

Age Assigned Using Scales

Age Assigned Using Otoliths

	1	2	3	4	5	6	7	8	9	10	11	12
1	14											
2		6										
3			5	1								
4			1	4	1							
5												
6												
7					1							
8						1						
9												
10								1				
11												
12												

Appendix 1. Continued

2003 Lake Thompson Yellow Perch
Age Assigned Using Scales

Age Assigned Using Otoliths	1	2	3	4	5	6	7	8	9	10	11	12
1		1										
2		22	3									
3		1	1									
4												
5												
6												
7												
8												
9												
10												
11												
12												

2003 Lake Thompson Walleyes
Age Assigned Using Scales

Age Assigned Using Otoliths	1	2	3	4	5	6	7	8	9	10	11	12
1	6											
2	1	39	3									
3			3	1								
4				6	7							
5					2	2						
6					1	1						
7												
8								1				
9							1					
10												
11												
12												

Appendix 1. Continued

2004 Lake Thompson Yellow Perch
Age Assigned Using Scales

Age Assigned Using Otoliths

	1	2	3	4	5	6	7	8	9	10	11	12
1												
2												
3			33									
4			1	1	2							
5												
6						1						
7												
8												
9												
10												
11												
12												

2004 Lake Thompson Walleyes
Age Assigned Using Scales

Age Assigned Using Otoliths

	1	2	3	4	5	6	7	8	9	10	11	12
1	5											
2		7	3									
3		3	23	7								
4			7	2	1							
5				2	2		1					
6				1								
7												
8						1		1				
9												
10												
11												
12										1		

Appendix 1. Continued

2005 Lake Thompson Yellow Perch

Age Assigned Using Scales

Age Assigned Using Otoliths

	1	2	3	4	5	6	7	8	9	10	11	12
1	6	1										
2		2	1									
3												
4				15	1							
5												
6												
7												
8												
9												
10												
11												
12												

2005 Lake Thompson Walleyes

Age Assigned Using Scales

Age Assigned Using Otoliths

	1	2	3	4	5	6	7	8	9	10	11	12
1	41											
2		5	5									
3			3	3								
4				12	4		1					
5				1	1	1						
6												
7												
8												
9												
10												
11								2	1			
12												

Appendix 2. Fall electrofishing catch per hour (CPUE) of age-0 and yearling walleyes and summer gill-net CPUE estimated by year class from scale-aged and otolith-aged walleyes collected from four eastern South Dakota lakes, 2003-2005.

Lake Herman Walleyes

			Gill-Netting CPUE					
	Electrofishing		Scale-Aged Fish			Otolith-Aged Fish		
Year class	Age-0 CPUE	Age-1 CPUE	2003	2004	2005	2003	2004	2005
2005	142							
2004	1	0			0.5			0.5
2003	293	54			10.5			10.5
2002	0	0	0.0		0.0	0.0		0
2001	133	7	11.2		0.0	11.7		0.3
2000	35	9	6.5		0.3	6.8		0
1999	5	0	0.8		0.0	0.3		0
1998	72	65	1.1		0.3	1.0		0
1997	93	104	0.5			0.0		
1996	24	11				0.3		
1995								
1994								
1993								
1992								

Lake Herman Walleyes

			Mean Length at Capture (mm)					
	Electrofishing		Scale-Aged Fish			Otolith-Aged Fish		
Year class	Age-0 CPUE	Age-1 CPUE	2003	2004	2005	2003	2004	2005
2005	142							
2004	1	0			215			215
2003	293	54			259			259
2002	0	0						
2001	133	7	354			355		479
2000	35	9	406		479	411		
1999	5	0	453			500		
1998	72	65	500		710	495		
1997	93	104	480					
1996	24	11				465		
1995								
1994								
1993								
1992								

Appendix 2. Continued

Lake Madison Walleyes

			Gill-Netting CPUE					
	Electrofishing		Scale-Aged Fish			Otolith-Aged Fish		
Year class	Age-0 CPUE	Age-1 CPUE	2003	2004	2005	2003	2004	2005
2005	128							
2004	2	0			0.2			0.2
2003	293	30		5.5	8.2		5.3	10.3
2002	12	2	1.0	0	2.1	1.0	1	0
2001	4	4	2.0	1	0.0	2.0	0.3	0
2000	15	0	0.0	0.5	0.0	0.0	0.3	0.2
1999	166	58	2.0	0.8	0.0	4.3	0.5	
1998			3.0	0.3	0.0	0.0	0.3	
1997			0.0		0.2	0.7	0.3	
1996			0.7			0.7		
1995			0.3					
1994								
1993								
1992								

Lake Madison Walleyes

			Mean Length at Capture (mm)					
	Electrofishing		Scale-Aged Fish			Otolith-Aged Fish		
Year class	Age-0 CPUE	Age-1 CPUE	2003	2004	2005	2003	2004	2005
2005	128							
2004	2	0			257			237
2003	293	30		216	306		216	312
2002	12	2	307		337	307	373	
2001	4	4	403	382		403	430	
2000	15	0		441		462	552	620
1999	166	58	516	535		516	493	
1998			522	575			575	
1997					620	546	551	
1996			556			628		
1995			614					
1994								
1993								
1992								

Appendix 2. Continued

Lake Sinai Walleyes

			Gill-Netting CPUE					
	Electrofishing		Scale-Aged Fish			Otolith-Aged Fish		
Year class	Age-0 CPUE	Age-1 CPUE	2003	2004	2005	2003	2004	2005
2005	9							
2004	87	64			2.3			2.3
2003	19	4		1	1.0		1.0	1.0
2002	122	22	0.3	1.25	1.0	0.3	1.5	1.0
2001	59	12	4.3	2	0.8	4.0	2.3	1.0
2000	5	6	1.3	0.75	0.3	1.0	0.3	0.0
1999		1	0.3	0.25	0.2	0.8	0.0	0.0
1998			8.0	0.25	0.0	7.8	0.5	0.2
1997			0.5	0.25	0.2	0.5	0.0	0.2
1996			0.3	0	0.0	0.3	0.0	0.0
1995			0.0	0.25		0.3	0.0	0.2
1994				0			0.3	
1993				0			0.0	
1992				0			0.3	

Lake Sinai Walleyes

			Mean Length at Capture (mm)					
	Electrofishing		Scale-Aged Fish			Otolith-Aged Fish		
Year class	Age-0 CPUE	Age-1 CPUE	2003	2004	2005	2003	2004	2005
2005	9							
2004	87	64			194			194
2003	19	4		251	314		251	314
2002	122	22	215	341	364	215	344	375
2001	59	12	339	408	409	336	413	405
2000	5	6	422	406	440	419	411	
1999		1	502	537	661	461		
1998			455	553		456	545	432
1997			558	615	687	477		661
1996			606			522		
1995				704		625		687
1994							704	
1993								
1992							615	

Appendix 2. Continued

Lake Thompson Walleyes

				Gill-Netting CPUE				
	Electrofishing		Scale-Aged Fish			Otolith-Aged Fish		
Year class	Age-0 CPUE	Age-1 CPUE	2003	2004	2005	2003	2004	2005
2005	5							
2004	290	50			18.3			18.3
2003	16	2		0.8	1.5		0.8	3.8
2002	78	4	1.7	2.7	3.8	1.4	2.3	2.4
2001	202	13	14.3	6.3	6.0	15.3	8.8	6.5
2000	231	10	1.5	3	2.5	0.9	1.1	1.4
1999	155	52	1.7	0.8	0.3	3.5	0.7	
1998			2.5	0.2	0.3	1.1	0.2	
1997			1.0	0.2	0.5	0.6	0	
1996			0.2	0.2	0.3	0	0.3	
1995			0.2	0	0.0	0.3	0	
1994				0.2	0.0	0.2	0	1
1993							0	
1992							0.2	

Lake Thompson Walleyes

				Mean Length at Capture (mm)				
	Electrofishing		Scale-Aged Fish			Otolith-Aged Fish		
Year class	Age-0 CPUE	Age-1 CPUE	2003	2004	2005	2003	2004	2005
2005	5							
2004	290	50			260			260
2003	16	2		262	350		262	359
2002	78	4	245	321	370	240	323	390
2001	202	13	312	347	419	315	352	412
2000	231	10	372	375	409	392	406	443
1999	155	52	453	472	433	484	486	
1998			497	508	427	503	408	
1997			508	532	626	474		
1996			600	607	617		558	
1995			599	0		600		
1994				681		561		623
1993								
1992							681	